Thermal Properties of Permanent Magnets

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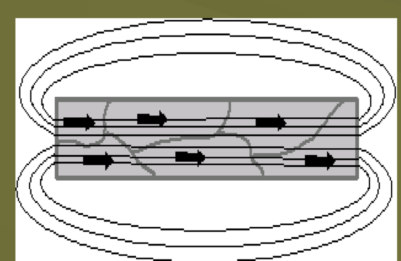
Magnets

All materials are made of very small particles called atoms. Within the atoms, the electrons generate magnetic fields as a result of their movement. There are only a small number of materials that are ferromagnetic, or able to be magnetized. In a magnetic material, forces that atoms exert on each other cause the magnetic fields surrounding atoms to line up with their magnetic poles pointing in the same direction. A group of atoms that have their magnetic poles pointing in the same direction is called a magnetic domain. A single magnetic domain may contain trillions of atoms, but it is still too small to see. In an unmagnetized piece of iron or steel, the molecules are arranged at random with the poles pointing in lots of different directions.

(Poles pointing in different directions)



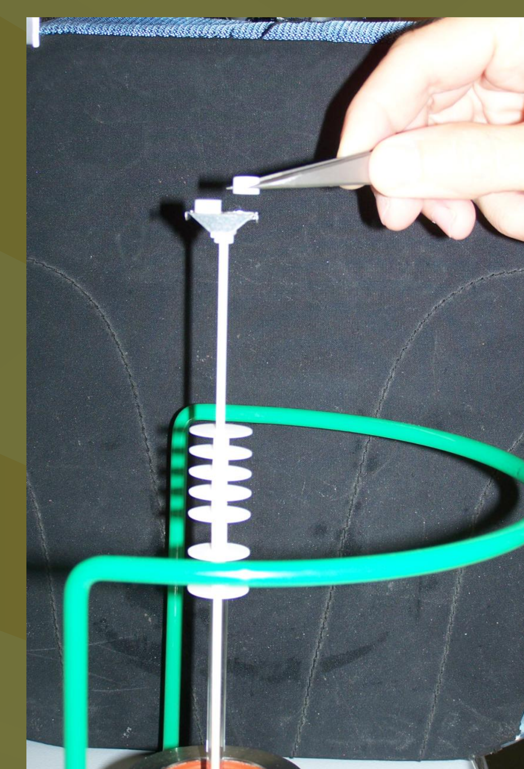
(Poles pointing in the same direction)

The Research

Permanent magnets are used in electric motors. Inside an electric motor, it is the attracting and repelling forces of the magnets that create rotational motion. Most of the magnets inside electric drive motors are made of neodymium-iron-boron magnet materials. The problem with these magnet materials is that they lose their magnetic strength when the motor gets hot, and they do not work very well. Scientists at Ames Lab have designed a high-performance permanent magnet alloy that replaces pure neodymium with the rare earth metals, neodymium, yttrium, and dysprosium. The result is a permanent magnet that operates with good magnetic strength at 200 degrees Celsius. Electric car developers are excited about this, but the permanent magnets are still too expensive to mass produce. Now the scientists are working on reducing the cost of the magnets while still maintaining excellent magnetic strength at temperatures of 200 degrees Celsius.

Thermal Properties of Matter

In solids, the arrangement of particles are closely packed. The movement of the particles vibrate about a fixed position held together by intermolecular bonds. In a liquid, the particles occur in clusters that are slightly further apart. These particles are free to move about between clusters and are confined within a vessel. Melting is a change of state from a solid to a liquid. Energy is needed to break the intermolecular bonds. This is called an endothermic reaction. Solidification, or freezing, is a change of state from a liquid to solid. Thermal energy is released as the intermolecular bonds are formed when the liquid particles come together to form a solid. This is called an exothermic reaction.



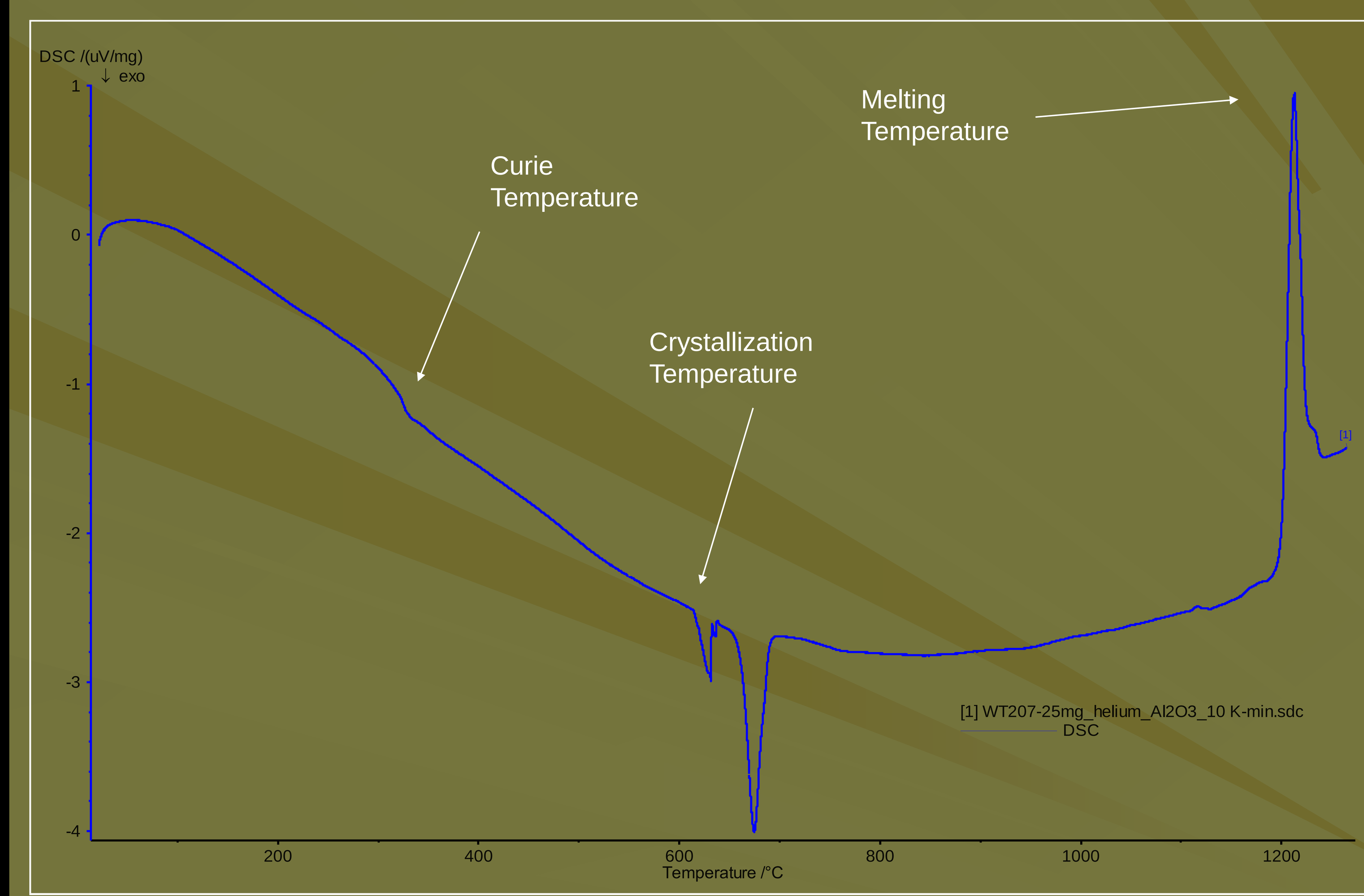
Differential Scanning Calorimeter

The Differential Scanning Calorimeter (DSC) is an apparatus used to study what happens to materials when they are heated. There are two crucibles. The material is placed in one crucible, and the other crucible is left empty as a reference. The two pans sit inside a small furnace. The computer is programmed to turn on the heater, and then it tells the furnace to heat the two pans at a specific rate (10 or 20 degrees K per minute). When the sample undergoes a physical transformation, such as melting or solidification, more (or less) heat will need to flow to it than the reference to maintain both at the same temperature. Whether more or less heat must flow to the sample depends on whether the process is endothermic or exothermic. By observing the difference in heat flow, the DSC can measure the amount of heat absorbed or released during physical transformations.

Current Research

The $Nd_2Fe_{14}B$ (2-14-1) permanent magnets that the scientists designed contain neodymium, dysprosium, and yttrium rare earth metals. This combination of rare earth metals allows the magnet to heat up to temperatures of 200 degrees Celsius and still remain a strong magnet. The scientists added cobalt to the iron in an effort to increase the Curie temperature, (the temperature at which the magnet becomes less magnetic.) Cobalt is very expensive and the market is not stable, so scientists are testing different amounts of cobalt in the magnet. The goal is to find the least amount of cobalt that would be necessary for the magnet to still have excellent magnetic properties at 200 degrees Celsius.

$Nd_2Fe_{14}B$



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